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CONTROL AND DISTRIBUTION PROTOCOL FOR A
PORTABLE ROUTER FRAMEWORK

TECHNICAL FIELD OF THE INVENTION

The present invention relates to a control and distribution protocol (CDP), and more particularly to a protocol for providing internet protocol routing functions to a host system such as, for example, a telecommunication switching or transmission system.

BACKGROUND OF THE INVENTION

When building internet protocol (IP) router capabilities with centralized dynamic route determination and distributed high performance IP packet processing capability, that are portable to many different host system architectures, it is necessary to have an efficient internal protocol for the transportation of control, maintenance, performance information, dynamic routing protocol message distribution messages, and routing table distribution management messages. Existing implementations of IP routers are system specific, and do not lend themselves to being portable to multiple operating environments.

A need exists for a protocol for use with existing and new communication system architectures to provide high performance internal communications capability for adding IP network routing functions to a host system such as, for example, an IP router, a telecommunication switching system, or a telecommunication transmission system. Such a protocol assumes the addition of an IP network route processing functioning component and multiple distributed IP packet flow processing functional components.

SUMMARY OF THE INVENTION

The present invention provides for a control and distribution protocol (CDP) which is implemented for transport across a backplane bus, through a high-speed serial link or through a switching fabric connection. The protocol includes an intra-system transport of dynamic routing protocol (DRP) IP messages, the distribution of routing information within the router, the transport of control and maintenance messages, and the transport of IP and multi-protocol label switching (MPLS) traffic between ingress and egress ports. The protocol further includes a dynamic routing and control driver which interacts with dynamic routing control applications to exchange messages that are to be transmitted to packet flow processors and to handoff messages received from packet flow processors. A packet flow processor driver is provided which services messages carried between the dynamic routing control and packet flow processors. An IP traffic interface provides transfer of IP L3/L2 protocol data unit (PDU) header primitive from the packet flow processors. Both the DRC driver and PFP driver include a framework transport interface.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention and for further advantages thereof, reference is now made to the following Description of the Preferred Embodiments taken in conjunction with the accompanying Drawings in which:

FIG. 1 is a block diagram of the present Control and Distribution Protocol;

FIG. 2 is a block diagram of the present Dynamic Routing and Control Driver illustrating driver functions;

FIG. 3 is a block diagram of the present Packet Flow Processor Driver illustrating driver functions;

FIG. 4 is a block diagram illustrating data link layer state transactions;

FIG. 5 is a diagram illustrating link layer messages between the Dynamic Routing and Control Driver and Packet Flow Processor Driver;

FIG. 6 is a table illustrating intra-system routing; and

FIG. 7 is a block diagram illustrating message paths.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present Control and Distribution Protocol (CDP) is an element of a Portable/Router Framework (PRF), and is a lightweight, connection oriented, datagram protocol that supports communications among multiple Portable Router Framework components. The CDP meets performance requirements of small to large router implementations and provides flexibility and expandability for new services and functions. The present protocol is lightweight enough so as not to degrade performance under very demanding service requirements, yet be robust enough to provide a high level of reliability.

The present Portable Router Framework (PRF) identifies several areas of functionality that communicate with each other to perform their functions. The CDP facilitates this communication and defines specific messages and procedures relative to layer 3 and layer 2 functionality. It is assumed that lower layer physical interconnection capabilities and formatting will be defined by the target, or host, system design. Therefore, the CDP is defined such that a number of different system architectures can use the protocol with minimal changes. CDP can be implemented for transport across a backplane bus, through a high-speed serial link or through a switching fabric connection. The two primary communication points are the Dynamic Routing and Control (DRC) and the Packet Flow Processors (PFP). CDP is primarily concerned with communications within the PRF, but CDP relies on host system maintenance, administrative and configuration capabilities to perform its work.

FIG. 1 illustrates the major components of CDP, generally identified by the numeral 20 and the main interconnections of CDP 20 with other functionality within a Portable Router Framework, generally identified by the numeral 22. The CDP 20 provides services for four major router functions: (1) the intra-system transport of Dynamic Routing Protocol Internet Protocol (DRP IP) messages, (2) the distribution of routing information within the router, (3) the transport of control and maintenance messages, and (4) the transport of IP and Multi Protocol Label Switching (MPLS) traffic between ingress and egress ports via a System Transport Media, generally

identified by the numeral 24. CDP Drivers 26 and 28 are either associated with the Dynamic Routing & Control (DRC) element main processor 30 or the Packet Flow Processor (PFP) elements 32. DRC elements 30 include, for example, routing software of a main processor. PFP elements 32 include, for example, telecommunication line cards, or interfaces to ethernet, and any data communication link for carrying IP traffic. In most systems there will be one online DRC driver 26. Depending on the system requirements, there may be a second DRC driver 26 utilized as a standby element that would assume control in the case the online unit experiences a failure. Other host systems may utilize multiple DRCs in a multiple virtual router arrangement. In all cases, an administrative process or other process specifies the relationship between DRCs and associated PFPs 32. There may be less PFPs 32 associated with each DRC 26 depending on the size and the partitioning of the host system. In all cases the PFPs 32 will communicate back to only one DRC driver 26. For Forwarded IP and MPLS traffic, each PFP 32 is required to communicate to all other associated PFPs 32.

The CDP (DRC) Driver 26 provides message transport services for applications executed by the DRC driver 26. CDP 20 is utilized by the DRC driver 26 to communicate with all of its associated PFPs 32. The Driver 26 has two main functions. The first is to interact with the DRC applications to exchange messages that need to be transmitted to PFPs 32 and to handoff messages received from PFPs 32. The second is to translate message format and routing information between the CDP protocol and the host system's transport media 24 protocol which in most cases is proprietary to the host systems architecture.

The CDP/DRC driver 26 upon initialization and receiving configuration (including system topology) information from the host system's administrative function establishes a link layer connection with all of its associated PFP 32 elements. To accomplish this connection, the driver 26 maintains an inter-system routing table that specifies link addresses of all active PFPs 32 and runs a CDP proprietary link layer protocol that drives the CDP link state machine. Link state status information is maintained for each DRC to PFP association. This link layer connection provides reliable transport services for messaging between the CDR/DRC

Application Programming Interface (API) and the CDP/PFP APIs. Below the CDP link layer is an interface to the host systems transport protocols and transport media 24. This interface 34,36 provides a portion of the required Portable Router Framework Host System Porting Specification.

Above the CDP Link Layer are the CDP message APIs. The APIs can work in either a push or a poll-and-pull mode for message transfer requests depending of the host systems needs. This mode is a configurable item. When a message is ready for transport, the CDP interrogates the information received from the application to determine how the message will be routed and if multicast is requested. Each API to the DRC code is assigned a message type indicator that is carried across the link in each datagram. The receiving side uses the message type indicator to deliver the message to the designated application. Each message may be addressed to a port, a PFP application or an IP address. The CDP translates these addresses to determine the host system address of the associated PFP. The CDP then formats the message and places it in the appropriate link layer queue for a specific PFP.

The CDP/DRC API is composed of three APIs 40, 42, and 44 to support the three types of messaging provided by the CDP. The three message types are Control and Network Management messages, routing table management messages, and IP formatted messages.

Control and Network Management API 40 allows the DRC control function to perform the following functions;

- Initialization
- Configuration
- System Status monitoring
- Synchronization
- Fault reporting and recovery
- Performance Monitoring and reporting

API 40 primitive contains the following information.

Send messages to a PFP or a PFP group

- Destination PFP ID or PFP Group ID
- Message Type

- Function or Action Opcode
- Arguments

Receive C&M message from PFP

- Source PFP ID
- C/M Indicator
- Event
- Arguments

The Routing Table Application API 42 allows the DRC to Initialize and maintain routing table information held in all PFPs 32. API 42 also provides for the monitoring and verification of the distributed routing table contents. Table status and fault events received from the PFPs are signaled up to the DRC routing distribution application. The R-API 42 primitive contains the following information.

Send routing table initialization and route update

- Transaction ID
- PFP ID or PFP Group ID
- Partition ID
- Information Pointer
- Information Size
- Information Check-sum

Receive PFP Routing Table Event

- Destination DRC application ID
- Source PFP ID
- Event
- Arguments

As shown in FIG. 2, DRP software sends and receives IP formatted messages through all external circuits that connect to other peer routers to gain knowledge of network topology. IP API 44 allows for the transport of these IP messages to and from the external interface circuits that are associated with PFPs that service IP network traffic. The DRC applications use a Logical Interface (LI) as a local representation of the actual physical port (and virtual connection (VC)) that may be associated with a remote router interface. It is the function of the CDP/DRC IP API

44 to prepare any IP message residing in any LI for transport to its associated outgoing router physical interface. This activity can be started by having the DRC software alert the CDP and push the message to the CDR/DRC IP API 44 or by having the CDP/DRC IP-API poll for any active LI and pull the message from the LI. The DRC and CDR will support both scenarios with the actual implementation dependent on the host system operating system capabilities. The CDP/DRC IP API 44 maintains association relationships for virtual connections assigned to ports and for ports assigned to PFPs. These associations can be used for multicast functions or for maintenance functions. The DP/DRC LI_API also maintains an association of the outgoing ports (w/VC) with their assigned IP address that is used as the Source Address within the outgoing IP packet.

The CDP/DRC IP API 44 primitive information is as follows.

Send IP message (DRC message push or CDP message pull)

- LI_ID; Logical Interface Identification
- IP message locator
 - Message ID
 - Index

Receive IP Message from PFP

- Source PFP
- Source PHY/VC
- IP Packet or Packet pointer

The CDP/PFP Driver 28 receives and transmits datagram messages from and to a host systems DRC function. Upon initialization and configuration the CDP/PFP Driver 28 establishes an link layer connection with its designated DRC. Following connection establishment the driver signals through its APIs that message services are available. The CDP/PFP Driver 28 has a one-to-one relationship with the designated DRC and provides services for the three types of messages carried between the DRC and the PFP. The CDP/PFP Driver has an additional requirement of facilitating transport through a traffic interface 50 of forwarded IP traffic from an ingress PFP (port) to an egress PFP (next-hop port) through the host systems transport media 24 as illustrated in FIG. 3.

The PFP Application API contains three message type APIs that correspond to the CDP/DRC APIs and interface to associated application functions in the PFP.

The Control and Management API 52 allows the control function in the DRC and PFP to communicate. API 52 interacts with the control element of the PFP 32 to deliver commands from the DRC. API 52 also accepts events generated within the PFP that need to be transported to the DRC for processing. The CDP/PFP C&M-API 52 primitive contains the following information.

PFP to DRC messages.

- DRC Source ID
- C/M Indicator
- Event #
- Arguments

DRC to PFP messages.

- Source DRC ID
- C/M Indicator
- Function Operator
- Arguments

The Routing Table API 54 allows communication IP routing information from the DRC to the PFP for use in routing IP datagram traffic. Routing Table initialization and update messages are communicated from the DRC. Table status messages and performance messages are communicated back the DRC. The CDP/PFP R-API 54 primitive information is as follows.

DRC to PFP messages

- DRC Source ID
- Message Type
- Function Operator
- Arguments

PFP to DRC messages.

- DRC Destination ID
- Event #
- Arguments

The IP messaging API 56 provides a path for locally addressed IP messages to reach the DRC applications. API 56 also provides for locally generated IP messages to be forwarded through I/O (Connections) ports assigned to a specific PFP. The CDP/PFP IP-API 56 primitive information is as follows.

PFP to DRC (router ingress) IP messages.

- Destination DRC ID
- IP Packet Locator (pointer)
- Source Connection / Port ID (PHY-VC)

DRC to PFP (router egress) IP messages.

- Source DRC ID
- Message Type
- Next-Hop (PHY-VC)
- L3/L2 Primitive information
- IP Message Locator (pointer)
- QQ# (Quality of Services Queuing Priority)

Referring to FIG. 3, the CDP IP Traffic Interface 50 provides for an efficient transfer of the IP L3/L2 PDU Header primitive from the PFP forwarding function to the CDP for the purpose of reconstruction of the modified IP packet header with the IP packet data. IF Traffic Interface 50 also provides for receiving forwarded L3/L2 PDUs from the Framework Transport Interface 36 and directing them to buffer memory 60 for output queuing. At this point a 'message pointer' is sent to the Quality of Service Queuing (QQ) 62 management function. The L3/L2 PDU is stored in buffer 64 supported by the host system.

Both the CDP/DRC Driver 26 and the CDP/PFP Driver 28 contain a similar functional block Framework Transport I/F 34 and 36. The Framework Transport Interface 34 and 36 perform several functions which are divided into two categories, Framework CDP functions and host system functions. For the Framework functions, the interface contains the CDP Link Layer protocol and performs a multiplexing/demultiplexing function for interacting with the CDP APIs. There is an intra-system address translation function to assist in intra-system routing of CDP datagrams. The host system functional group is system specific and is responsible

for message integration, including formatting, addressing and protocol execution, with the host systems transport media. Between the two functional groups is the CDP Interface that supports the Portable Router Framework portability.

The Framework Transport Interface 34 and 36 after initialization and configuration, establish a link layer connection between the system provisioned DRC and each provisioned PFP 32. With the links established the CDP APIs are notified that the link is available for message transport. The FT I/F 34 and 36 use the Message type indicator carried within the message header to deliver datagrams to the appropriate CDP API.

The CDP Link Layer protocol is responsible for establishing a communication link between the DRC and its associated PFP modules. When the Link Layer connection is established the CDP APIs are signaled that message services are available to the application layer functions.

The DRC is considered to be the controlling, or master, element. During the initialization phase both the DRC side and the PFP side of the link start timers. On the expiration of the timers, the protocol driver will issue either a command from the DRC or an event from the PFP to alert the other end that the a host system layer 1 connection has been made and therefor CDP can begin its establishment phase. If the messages are unsuccessful, the timers are restarted. This process will continue until the host system connection is set. The host system is responsible for establishing a system transport media connection to support CDP communications. Once the initial messages are received, The DRC side will ask the PFP for topology information. When this is received from the PFP side the DRC side will download configuration information. The PFP will stay in a configuration state until it is told to move to a link established state in coordination with other PFPs. While in the configuration state the PFP side will run a timer and on expiration of the timer will send a 'configuration state timer expired event'. In the link established state, CDP will accept application layer datagrams, events or commands, for transport across the link. Also during the link established state the DRC side will issue 'Keep-alive' commands which will be acknowledged by the PFP side. Along with the 'Keep-alive ACK' event from the PFP side will be PFP element status information which will

include routing table status information which may identify the last update ID and current table check-sum. The DRC side can command the PFP side to reset in which case the PFP CDP link layer will stop service and move through the Out-Of-Service state and attempt to reestablish a connection or the DRC side can leave the PFP in an Out-of-Service condition.

FIG. 4 shows the CDP/PFP link layer state machine transitions. The timers associated with each state are set to default values on initialization but can be modified dynamically by the CDP/DRC Link Topology Information Update command messages.

The CDP Link Layer message set is utilized to establish communications between the DRC and a PFP and is shown in FIG. 5.

CDP/DRC Link Commands

- Who is present? (Topology Query)
- System Topology Information Initialization
- System Topology Information Update
- Establish
- Keep-alive
- Reset

CDP/PFP Link Events

- State-Up
- Topology Query Response
- Timer (T_n) Expired
- Keep-alive ACK
- Reset ACK

In order for the Framework Transport I/F 34 and 36 to accomplish their function, integration with the host system requires a definition of interworking procedures and exchange of configuration and addressing information. CDP requires the capability to establish communications with all associated system elements and therefor needs to maintain a table of addresses of each element that makes up the router function. This information needs to be supplied by the host system. The CDP

design defines a specific interface for integration with the host system's message transport implementation. It is the responsibility of the host system to implement their side of the interface.

In order to establish communications between Portable Router Framework elements, CDP 20 defines the address model that is required. As part of the host system porting development, the host systems administrative and maintenance is required to interact with CDP to establish and maintain intra-system routing information. This routing requires a common understanding of naming and addressing of key router elements. In this regard the DRC and PFPs routing function are defined. Also, the host system's router ports and associated virtual connections are defined. For portability, the host System Fabric Interface Address (SFIA) which identifies the host systems address for the Framework element is used as the integration key. To facilitate CDP integration, the following associations are established:

Address Model;

$DRC(n) = SFIA$

$DRC(n) \text{ Application} = SFIA + \text{Message Type}$

$PFP(n) = SFIA$

$PFP(n) \text{ Partition} = SFIA + \text{Partition Number}$

$PFP(n) \text{ Application} = SFIA + \text{Message Type}$

$PHY(n) = SFIA + \text{Card Port number}$

$(PHY \text{ system level} = \text{Cabinet} + \text{Shelf} + \text{Slot} + \text{Port\#})$

$\text{Next Hop} = PHY(n) + VC$

$DRC_LI \text{ (from PFP)} = DRC(n) + PHY(n) + VP\#$

$DRC_LI \text{ (from DRC)} = IP \text{ Address}$

$DRC_L1 \text{ (from C\&M to CDP)} = DRC(n) + PHY(n) + VP\#$

The message structures for carrying CDP protocol datagrams between the DRC and the PFPs is shown below:

IP Message Transport Message Structure (DRC to PFP)
 [PFP ID#] + [DRC ID#] + [Message type] + [Next-Hop] + [IP Packet]
 (16 Bits) (8 Bits) (3 Bits) (m Bits) (n Bytes)

Control & Maintenance Message Structure (DRC to PFP)

[PFP ID#] + [DRC ID#] + [Message type] + [C/M Indicator] + [Function] +
 (16 Bits) (8 Bits) (8 Bits) (1 Bits) (15 Bits)

[Arguments]
 (n Bytes)

Routing Table App. Message Structure (DRC to PFP)

[PFP ID#] + [DRC ID#] + [Message type] + [Function] + [Arguments]
 (16 Bits) (8 Bits) (8 Bits) (8 Bits) (n Bytes)

IP Message Transport Message Structure (PFP to DRC)

[DRC: ID#] + [Message type] + [Source PHY/VP] + [IP Packet]
 (8 Bits) (8 Bits) (x Bits) (n Bytes)

Control & Maintenance Message Structure (PFP to DRC)

[DRC ID#] + [Source PFP ID#] + [Message type] + [C/M Indicator] + [Event] +
 (8 Bits) (16 Bits) (8 Bits) (1 Bits) (7 Bits)

[Arguments]
 (n Bytes)

Routing Table App. Message Structure (PFP to DRC)

[DRC ID#] + [Source PFP ID#] + [Message type] + [Event] + [Arguments]
 (8 Bits) (16 Bits) (8 Bits) (8 Bits) (n Bytes)

The following are the assigned CDP message Types;

Message Type 00H - CDP Link State Message

Message Type 01H – IP-API Message

Message Type 02H - C&M-API Message

Message Type 04H – R-API Message

CDP uses information within the API PDUs to determine the host system's SFIA for destination routing through the host systems transport media. DRC applications may have a need to multicast certain messages to multiple PFPs. Therefore, included are tables that allow multicasting to groups of IP addresses, groups of PFPs and groups of physical ports. Table identification required to perform the intra-system routing function is shown in FIG. 6.

FIG. 7 illustrates message paths between Drivers 26 and 28 via the media 24.

Whereas the present invention has been described with respect to specific embodiments thereof, it will be understood that various changes and modifications will be suggested to one skilled in the art and it is intended to encompass such changes and modifications as fall within the scope of the appended claims.

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